Some Say Stormwater—We Say Source Water

Bringing Clarity to a Muddy Situation: Assimilation of Reservoir Construction Site Stormwater

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Suffering from a continuing drought in Southwest Florida and facing high construction costs for its reservoir, the Peace River Manasota Regional Water Supply Authority developed a unique project approach that saved the utility an estimated $10 million in construction costs, yielded approximately 1.5 billion gallons of additional water supply, and eliminated the greatest possibility for off-site environmental impacts during the 18-month construction project.

The utility captured stormwater runoff from an 800-acre reservoir construction site and diverted the captured water to its existing potable water treatment plant, eliminating the requirement for the reservoir contractor to construct stormwater management facilities. Turbidity in this stormwater runoff often exceeded 2,000 NTU, which, combined with a diesel fuel spill and the scramble to remove dozens of portolets from the site during named storms, were some of challenges that were faced and overcome as a part of this innovative project. This article offers a summary of how the project was conceived and implemented and the lessons that were learned.

Background

The Authority is a regional water supplier for a four-county region located in Southwest Florida (Charlotte, DeSoto, Manatee and Sarasota counties). The agency's main operations center is the Peace River Facility (PRF), which treats water withdrawn from the Peace River. Growing needs in the region drove the utility to double the PRF treatment capacity from 24 to 48 million gallons per day (MGD) and to construct a new 6.0 billion gallon (BG) off-stream reservoir.

This $171 million public works project was the largest of its kind ever built within the four-county region and was made possible in part with $80 million in cooperative grant funding from the Southwest Florida Water Management District and the Florida Legislature, with another $9 million in federal grants administered by the U.S. Environmental Protection Agency. Figure 1 presents an aerial view of the Peace River, the PRF, and its two off-stream reservoirs taken in late 2009.

To build the new reservoir, 800 acres of improved pasture, palmetto prairie, and shallow herbaceous wetlands would be disturbed. Significant volumes of surface water were expected from stormwater runoff, and groundwater seepage collected by an extensive shallow-rim ditch system would need to be pumped out continuously to keep the reservoir site dry enough to be workable.

The large site required continuous dewatering for 16 months, with dewatering volumes approaching 10 million gallons per day (MGD) during July and August 2008. Figure 2 depicts the conventional stormwater management approach that would have involved constructing approximately 100 acres of temporary stormwater collection and treatment systems to capture, treat, and release stormwater from the site.

Realizing an Opportunity

Project team members realized the challenge in managing stormwater runoff from such a large site in a manner that would avoid environmental impacts and possible construction halts because of excessively wet conditions. At the time, however, Southwest Florida was undergoing an extensive drought that was taxing both surface and groundwater systems alike, so every possible water source was being considered.

One of the project's key success factors

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FIGURE 1: PRF with new 6-BG Reservoir in far Background (Aug. 2009)

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was that Reservoir No. 1 is a man-made impoundment, not a natural lake, so that diversion of turbid water into this water body would not constitute impact to a natural system. Team members realized that the approximately square-mile new reservoir construction site had the potential to yield about 1 BG per year if that water could be captured and put to beneficial use.

At the time, the Authority was using up to 6 BG of raw water per year to meet its customer demands. Total annual rainfall on the 800-acre site was projected to amount to approximately 15 percent of the Authority's annual raw water needs, so it appeared that the construction water run-off could be assimilated handily. The most critical piece of the puzzle would be projecting water-quality characteristics at the construction site and assessing whether the treatment systems in place at the PRF would be suitable without costly, significant retrofitting.

If successful, this plan would eliminate the need for extensive stormwater management facilities at the new reservoir construction site. It also would allow the contractor to focus on the primary task—building a reservoir—instead of being distracted by treating stormwater and dealing with environmental impacts.

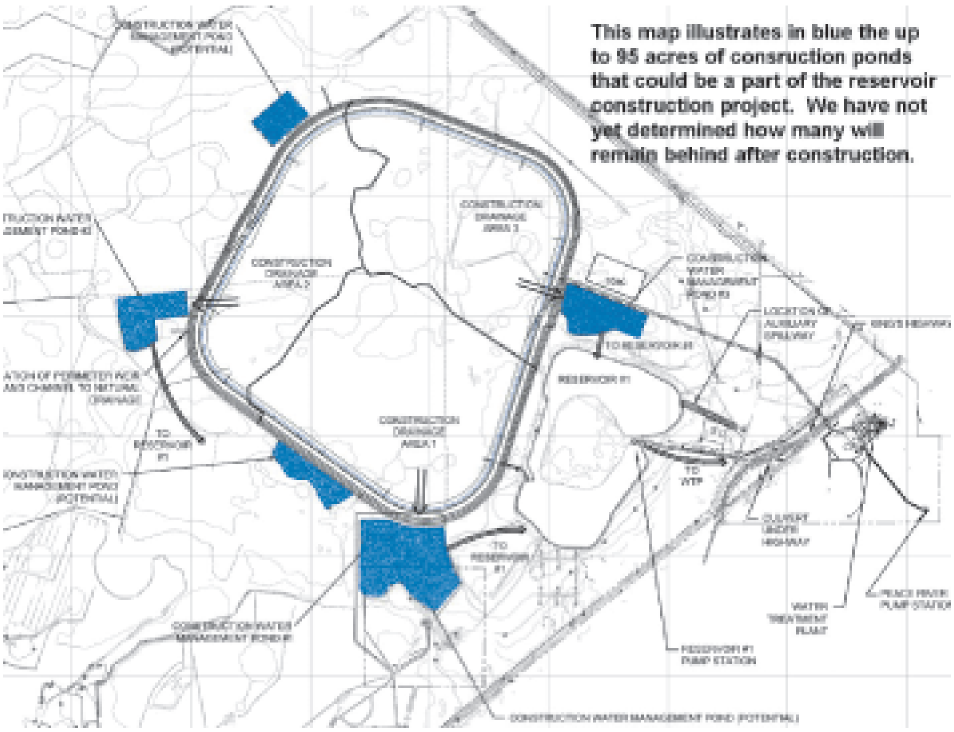
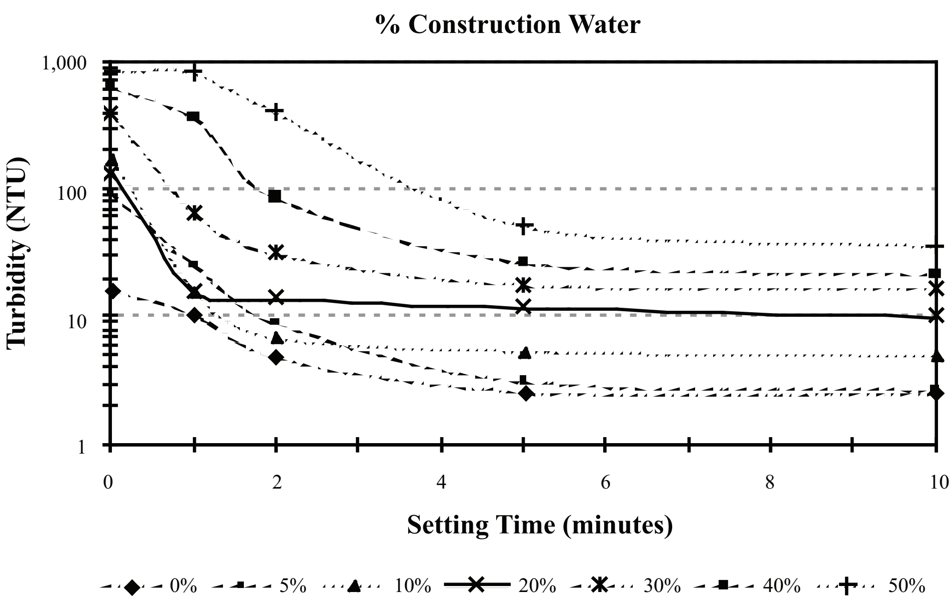


FIGURE 2: Option to Construct Temporary Stormwater Collection System

FIGURE 3: Settling Curve for Scenario #1



Exploratory & Bench-Scale Testing

Extensive testing was needed to evaluate the feasibility of the concept and ultimately to gain acceptance from the Florida Department of Environmental Protection (FDEP) to process the construction water run-off in a public water supply facility. Project team members worked collaboratively with FDEP staff to develop testing protocol to amass a body of data that would speak to project feasibility. Surface water, shallow groundwater, and soil samples were all analyzed to ascertain the type and nature of colloidal suspensions and general water quality that might be expected in site runoff.

Composited soil samples were elutriated to release colloidal silt and clay in an attempt to simulate the muddy water expected to be generated in rainwater runoff and by the churning tracks and treads of heavy equipment. Bench-scale jar test scenarios were performed to determine effects of construction/river-water blend ratios on settling characteristics and turbidity removal.

Each scenario consisted of water blend ratios ranging from 0 percent to 50 percent for construction/river water. Bentonitic clays were planned as a seepage block curtain underneath the reservoir berm embankment, and jar tests were even conducted with bentonite added to assess how its presence in the runoff might affect the ability to treat this water.

The full body of testing and analysis is too lengthy to attempt to detail in this article. Here is a summary of some bench scale jar testing results:

Scenario #1 – Vary alum dose to achieve constant pH of 5.8 (Figure 3).

- Increased construction/river-water blend ratios resulted in decreased alum dosages because the construction water lowered available alkalinity to form aluminum hydroxide ($Al_2(OH)_2$) floc. As a result, the low alkalinity/high construction-water blends became cloudy for the lack of available alkalinity.
- Achieving settled turbidity of <5 NTU was achievable only for construction/river-water blends of less than 5 percent.

Scenario #2 - Constant, high alum dose pH adjusted with caustic soda to achieve constant pH of 5.8 (Figure 4).

- Settled turbidities <5 NTU were achievable for the blends with the exception of the 50-percent construction/river-water blend.
- Hence, it was decided to dose construction-water blends with a constant high alum

dose of 130 mg/L and adjust pH to 5.8 using caustic soda to provide additional available alkalinity for floc formation.

Scenario #3 - Constant, high alum dose pH adjusted with caustic soda to achieve constant pH of 5.8 plus bentonite (Figure 5).

- Settled turbidities <5 NTU were achievable for the blends with the exception of the 50-percent construction/river-water blend.
- Bentonite did not affect settleability adversely.

Utility Acceptance, Safeguards & Agency Approval

The extensive testing proved that the existing conventional aluminum sulfate coagulation/sedimentation/filtration processes at the PRF would be sufficient and the product water would meet all applicable drinking water standards. Risk/benefit analysis tipped toward moving forward with the project, and FDEP approval was sought and received for it.

Construction plans were developed embodying this concept with the first contractor activity being to build a five-mile long, five-foot high berm around the entire site to contain all site water. Specific project controls were planned with the goal of minimizing negative impacts to water quality. These controls included:

- Restricting areas for major equipment maintenance and refueling depots to outside the construction footprint.
- Piping all construction water diversion to a single location, rather than having pipes pumping water into Reservoir No. 1 at multiple locations.
- Installation of multiple floating hydrocarbon containment boom systems around the outfall to Reservoir No. 1 in case of a fuel spill.
- Baffled ends installed on construction water outfall pipes to prevent the pipes from "jetting" their contents away and under floating booms.
- Daily inspection of all diesel powered portable pumps and the positioning of fuel tanks at least 50 feet from the edge of any ditch or canal.
- Relocation of all portolets to outside the construction footprint with the approach of any named storm.

The project was bid with Barnard Construction Company Inc. as the low bidder. During the next two years, all stormwater and rim ditch pumping water from the 800-acre site was ultimately treated and used for drinking water.

Putting the Plan into Full-Scale Operation

The plan was put into effect in January 2008. Turbidity levels in Reservoir No. 1 rose and fell in response to the mixture of stormwater diverted from the construction site compared with raw surface water pumped from the Peace River. Figure 6 presents a photograph of the main dewatering sump where all the contractor's rim ditches were directed. This sump was a small, quarter-acre pond that was kept pumped down.

Reservoir No. 1's raw water turbidity values over the course of the project are presented in the graph shown in Figure 7. As the graph displays, the raw water turbidity in Reservoir 1 exceeded 500 NTU at times in the summer of 2008, but with the end of the rainy season in October, it fell steadily until it was back below 20 NTU by January 2009.

Figure 8 presents a graph of the maximum settled water turbidity values for the PRF over this same period. Turbidity values were generally below 3 NTU with the exception of the five-month period of August through December 2008, corresponding to the most challenging raw water conditions.

Figures 9 through 15 present aerial photographs of the Reservoir No. 2 construction site from the southeast with a portion of Reservoir No. 1 visible in each photo. This series of photographs begins with January 2008 when construction was just getting underway and ends with September 2009, at the conclusion of the project and with Reservoir No. 2 half filled. Note that the color tone of Reservoir No.1 changes through the seasons in response to muddy construction water diversion

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FIGURE 4: Settling Curve for Scenario #2

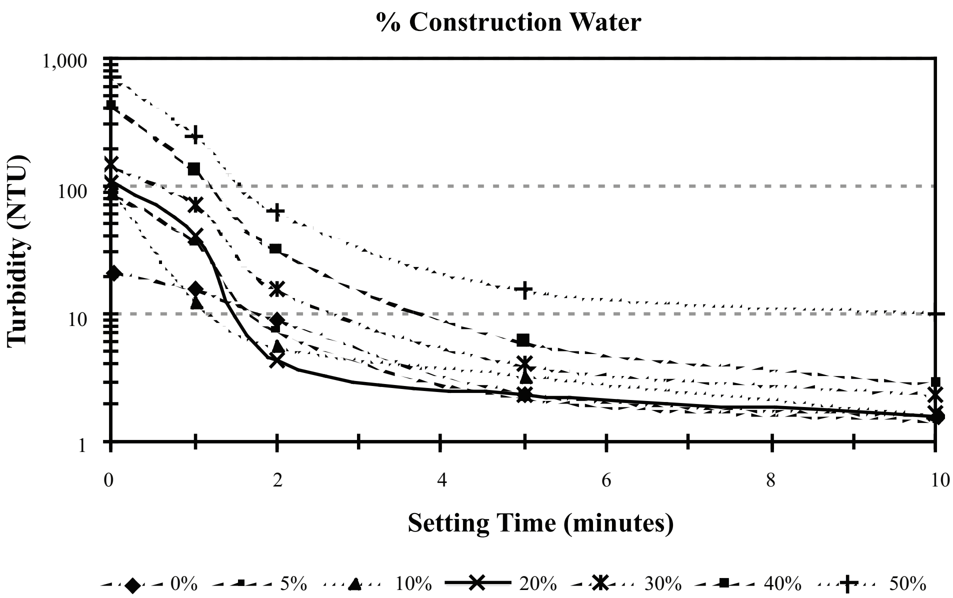

FIGURE 5: Settling Curve for Scenario #3

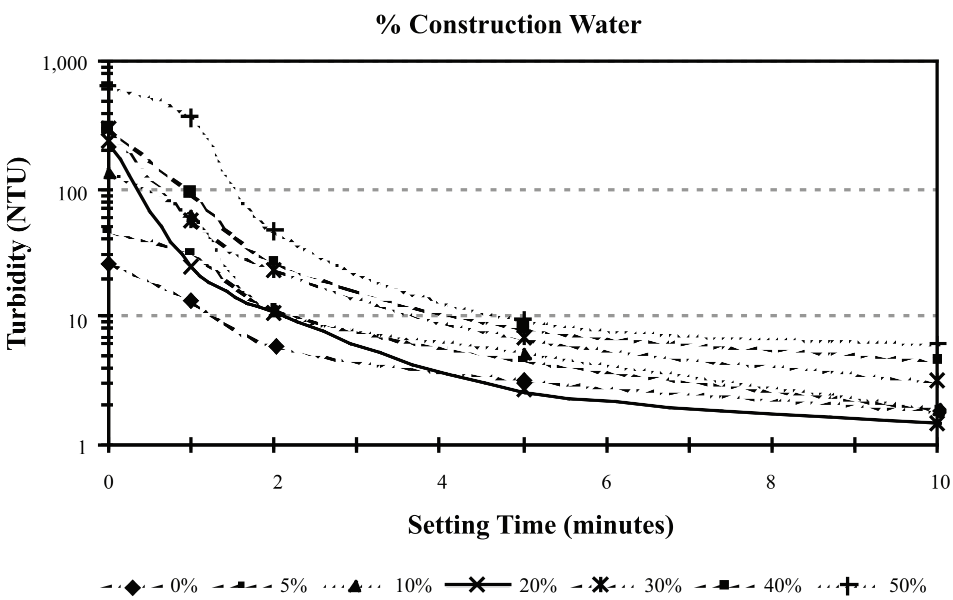

FIGURE 6: Construction Site Stormwater Run-Off Pump Station Inlet (July 28, 2008)

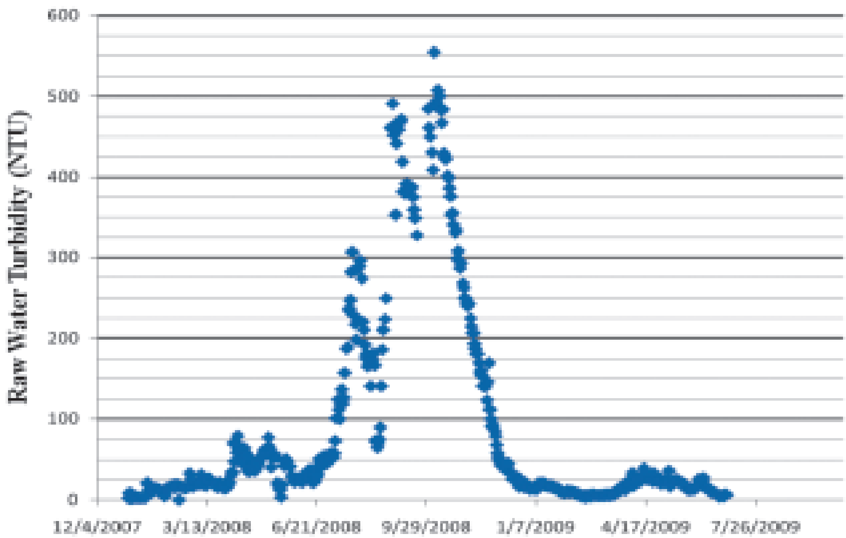

FIGURE 7: Reservoir No. 1 Turbidity (January 2008 – June 2009)

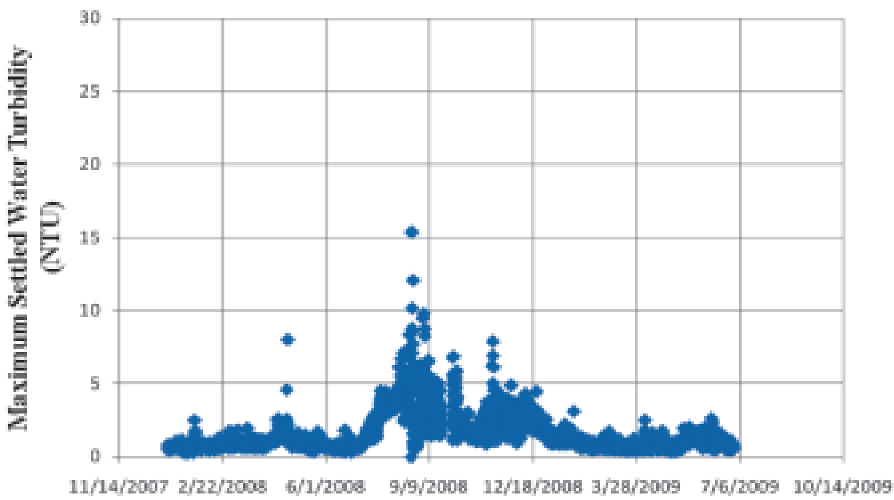

FIGURE 8: PRF Settled Water Turbidity (January 2008 – June 2009)

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off the Reservoir No. 2 site.

Operational Control

Treating the highly turbid reservoir construction runoff successfully was both a technical and operational challenge at times. Jar testing was done frequently to confirm needed chemical dosages. The turbid water being pumped into Reservoir No. 1 entered about a quarter of a mile from the reservoir pumps feeding the water treatment plant, making it possible to watch as plumes of turbidity slowed migrated across the reservoir toward the intake pumps after rainfall events. Often samples were collected by boat at various distances from the intakes for jar testing so utility staff could evaluate what they might expect two, four, or seven days from the present.

Utility staff intentionally maintained the level of Reservoir No. 1 two feet below full (representing about 60 MG) to leave room for the construction contractor to pump water after rain events. Pumping had to be stopped or curtailed only once, during early August 2008 after more than 20 inches of rain had fallen on the site earlier that July. It took about a week before unrestricted pumping was resumed. Throughout the project, the contractor and utility staff maintained close coordination of pumping activities.

Supplemental Use of Polymer in Construction Water

With the extreme summer 2008 rainfall amounts, turbidity levels rose markedly as the proportion of stormwater in the reservoir compared with river water increased. In July 2008, utility staff began adding up a Poly DADMAC (cationic polymer) to the construction water as it entered Reservoir No. 1 as a means of enhancing the settling of solids (*Note*: Although polyacrylamide polymers actually performed better, there was concern about the possibility of detrimental effects on native fish populations within Reservoir No. 1).

The polymer was added at the suction side of the dewatering pumps, taking advantage of the pump's energy and turbulence for mixing. There were no facilities for carefully controlled flocculation; the dosed water simply spilled out into Reservoir No. 1 through the normal HDPE discharge lines. Although applied under less than ideal conditions, sampling reflected that this supplemental treatment with the Poly DADMAC polymer had a beneficial effect and may have reduced turbidity in the construction water by as much as 25 percent.

Solids Contact Units vs. Conventional Rectangular Flocculation Basins

When the project started, the PRF had 12 MGD of treatment capacity using solids contact

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1) FIGURE 9: Reservoir No. 1 on January 2008: Only slight Discoloration on South Side
2) FIGURE 10: Reservoir No. 1 on April 2008: Major Impact to South Side Evident
3) FIGURE 11: Reservoir No. 1 on October 2008: Turbidity has Migrated to Both Sides
4) FIGURE 12: Reservoir No. 1 on January 2009: Conditions Clearing Up
5) FIGURE 13: Reservoir No. 1 on March 2009: Very Little Construction Water Pumping
6) FIGURE 14: Reservoir No. 1 on June 2009: Almost Ready to Fill Reservoir No. 2
7) FIGURE 15: Reservoir No. 2 on September 2009: New Reservoir is Half Full

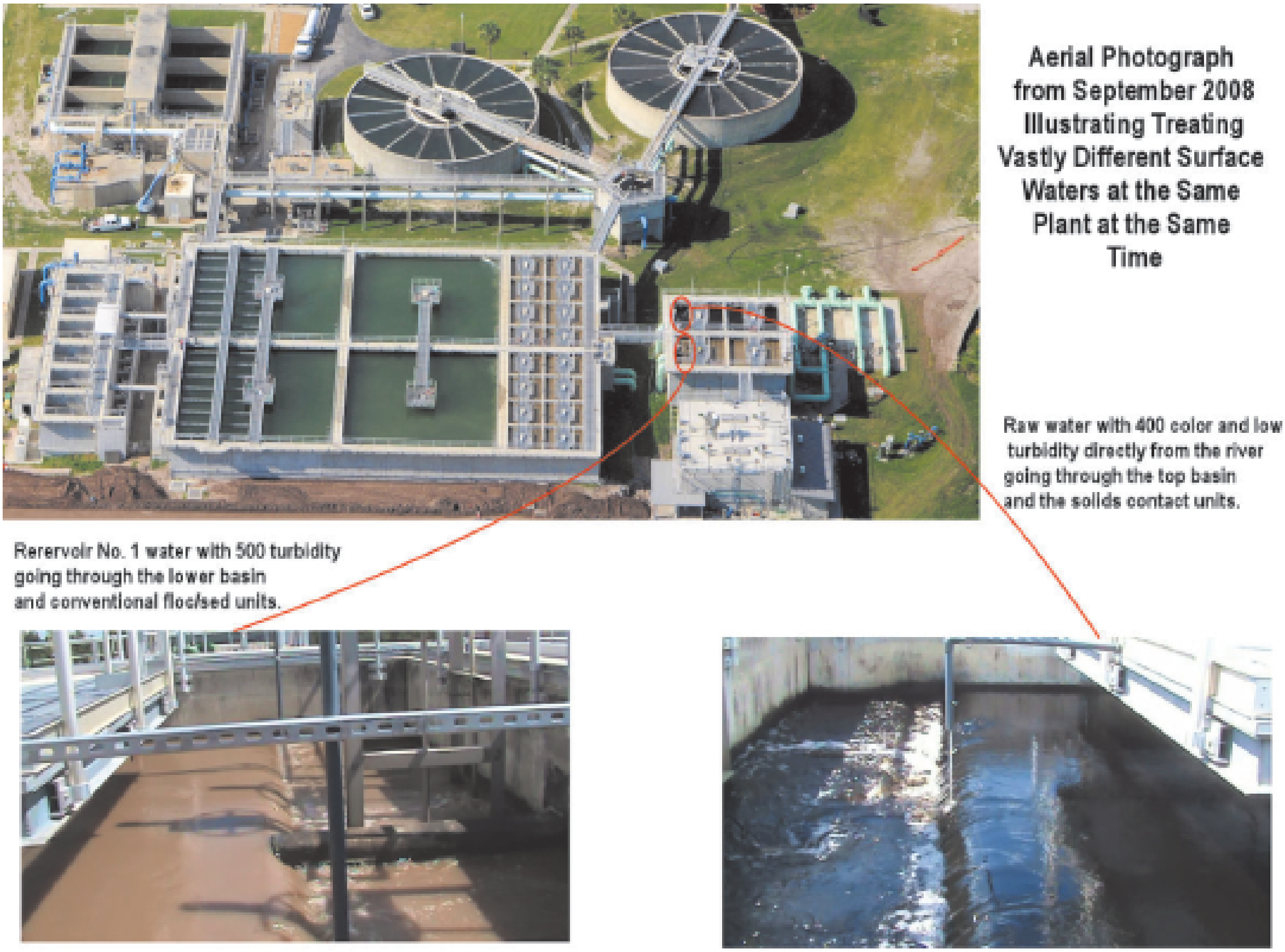

FIGURE 16: Two Water Treatment Plants in One

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units and 12 MGD of treatment capacity with conventional, rectangular flocculation/sedimentation basins. The solids produced during coagulation were high in clayey colloids and behaved differently than typical aluminum hydroxide organic sludges; they were "stickier."

Sludge blankets in solid contact units were extremely dense and high recirculation rates were needed to keep them suspended. Settled water turbidities of less than 0.25 NTU were not uncommon as the dense sludge blankets effectively filtered out most particles. In contrast, the conventional rectangular basins generally produced settled water turbidity values of 2 to 4 NTU.

The sludge blankets in the solids contact units spontaneously collapsed on a number of occasions. Speculation is that solids reached a critical mass density promoting rapid accreting of floc into large masses. The spark of a spontaneous collapse was sometimes a change in flowrate, though other times it appeared more or less randomly.

Once a sludge blanket collapse had occurred, the sticky, dense sludge would foul the sludge rake and set off torque alarms. These units often had to be drained completely and hosed out to remove the clayey, sticky sludge before being restarted. Sludge blanket depth and density was adjusted by controlling sludge blowdown rates and polymer dosages and proved to be the chief operational challenge of this project.

Eventually, utility staff elected not to use the solids contact units to continue to treat the high turbidity river/construction-water mixture because of the sludge blanket instability issues. Low-turbidity, high-color raw river water was pumped to these units instead, while the muddy construction water continued to be treated with the conventional rectangular basin flocculation/sedimentation facilities (see Figure 16).

The photograph in Figure 16 illustrates an extremely rare event which the authors believe may never have taken place before; that is, the treatment of two vastly different surface waters at the same time at the same water plant. One half of the water plant was treating low-turbidity, highly colored water pumped directly from the Peace River, and the other half of the facility was treating extremely high-turbidity water pumped from Reservoir No. 1. This remarkable achievement was carried out continuously for three months from September through November 2008 and is a testament to the capability of the facility operations staff and the value of having multiple piping, valve, and pumping options available at a water treatment plant.

By September 2008, under the latest plant expansion, included additional solids contact units were becoming operational. Utility staff used the muddy reservoir construction water to perform the shakedown and performance testing on these new units with all treated water recycled back to the reservoir. Some of the same issues with sludge blanket stability were observed with the newer solids contact units as had been experienced with the older units; however, because that water was being recycled to the reservoir rather than used as potable supply, extensive parametric testing opportunities were possible.

FIGURE 17: Diesel Spill Storage Tank Lying at Bottom of Erosion Gulley

Filtration

Accelerated mud ball formation was observed in filters not equipped with air scour and for which only marginal backwash/bed expansion was possible. These filters had to be meticulously hand cleaned while continuously backwashing over several days using an air sparger lance to break up mud balls

Overall, however, filter performance was generally good with filter run times as long as 72 hours when settled water turbidities remained below 0.5 NTU. In fact, the settled water was so low in solids, it often took a lengthy period for filters to ripen, making them sensitive to changes in flow or settled water quality.

Two filters were the most problematic and required backwashing much more frequently than the others. Later when these two filters were rebuilt, it was discovered that they suffered from poorly grouted underdrains.

Incidents & Unintended Consequences

Most large projects suffer from a number of incidents in which things do not go exactly as planned or in which unintended consequences crop up that may be of wide interest. These sidebar issues can often be intriguing, and several of those types of issues are related here.

The Diesel Spill

Perhaps the single most distressing moment during the entire project came the morning of May 15, 2008, when it was learned that a 500-gallon portable diesel storage tank had been undercut by erosion and had overturned into the rim ditch system (see Figure 17). Fortunately, the rim ditch system was segmented by roadways with submerged culvert pipes, so most of the floating diesel fuel was contained. The main dewatering system also employed a flexible suction pipe that was suspended by floats about two feet below the water surface, which also helped prevent the floating diesel fuel from being pumped to Reservoir No. 1.

Cliff Berry Environmental Services Inc. of Tampa responded immediately and commenced an extensive soil and water cleanup effort over the next several days. The contractor estimated cleanup costs related to this spill were in excess of $100,000. After cleanup, analyses showed no contamination of Reservoir No. 1 and the contractor was permitted to resume construction-site pumping after all ditches, pipes, and pumps had been cleaned and sampled to verify complete mitigation of all hydrocarbon contamination.

The cause of this event was human error. The main site dewatering station consisted of three 100-horsepower pumps pulling out of a small lake about one quarter acre in size. One pump ran continuously and the pumps were alternated every few days.

On the night of May 14, 2008, a worker switched pumps but did not realize that someone had opened a valve on that pump's 12-inch diameter HDPE discharge line so that instead of pumping water to Reservoir No. 1, the water was pumped about 200 yards and then ran out the valve opening and right back to the rim ditch system, cutting a deep gulley that undercut the pump and diesel tank on its way back to the small lake. Eventually, the diesel tank fell into the gulley, along with the pump. If the worker had remained onsite just 10 minutes longer, he likely would have seen the beginning of the return flood and would have been able to close the offending open valve without incident.

Algae Growth Curtailed

An unexpected benefit from introducing the highly turbid water into the reservoir was that blue-green planktonic algae problems virtually ceased. It is not uncommon for the utility staff to apply several tons of copper sulfate per week during algae bloom periods to control these nuisance species, but without the ability for sunlight to penetrate into the water more than a few inches, conditions proved too challenging for photosynthesis-dependent organisms to flourish.

Massive Sandbar Formed

Construction water pumped from the construction site unavoidably included sand—so much sand, in fact, that a small underwater mountain of sand accumulated in Reservoir No. 1 measuring up to 16 feet high and estimated to be about an acre in size, comprised of up to 10,000 cubic yards of material. This sand bank was left in place because it reflected less than half a percent of Reservoir No. 1's total volume and the cost to dredge it to recover the lost storage volume was not deemed worthwhile.

Summary

The Authority used its treatment plant and Reservoir No. 1 in an innovative way to bolster public supplies by capturing runoff and dewatering flows from the 800-acre Reservoir No. 2 construction site during an extended regional drought. It is estimated that over 1.5 billion gallons of water were harvested from this site over the 18-month construction project and used for the public drinking water supply. This project also saved the utility an estimated $10 million in construction costs that would have been incurred if the reservoir construction contractor had been compelled to construct and manage construction water management systems for the project.

This plan was developed through careful testing and consideration; however, it is often difficult or even impossible to emulate full-scale processes on a bench-scale format. The instability of the sludge blanket in the solids contact units once they were heavily populated with the colloidal clays could not have been predicted from bench scale testing. As it turns out, the conventional rectangular flocculation/sedimentation basins proved more suitable and reliable for the treatment of the high-turbidity water.

Water is a precious resource. This project reflects a successful conglomeration of ingenuity, innovative planning, and hard work by many dedicated engineers, regulatory personnel, and, most importantly, the operations staff who tirelessly overcame the many difficulties signified with implementing this project.

It would have been far easier to simply pay more and require the reservoir construction contractor to manage his/her own construction water. This project stands as a model to be emulated by future regional water supply resources projects.